Alternative Surveillance Fast Time Simulation with Sensor Uncertainties and Mitigation

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Background

- On March 6th, SC-228 selected a Detect-and-Avoid (DAA) Well Clear (DWC) for non-cooperative aircraft (previously called DWC2) for additional studies
  - The non-coop DWC and Phase 1 DWC yield comparable safety metrics such as the NMAC risk ratio and loss of DWC ratio
  - Simulations were based on
    - Truth aircraft states
    - Phase 1 pilot response model in a deterministic mode
    - Version 1.0 of the DAIDALUS algorithm

DWC	Γ_{mod} (sec)	HMD* (ft)	h* (ft)
Non-Coop	0 sec	2200 ft	450 ft
Phase 1	35 sec	4000 ft	450 ft

Objectives

- Investigate the effect of limited surveillance volume and realistic radar noise on DAA performance
- Evaluate the ability of the sensor uncertainty mitigation (SUM) feature of the DAIDALUS algorithm to improve DAA alerting and guidance

Fast Time Simulation Schedule

Simulation Type		Low C-SWaP Operations	Phase 1 Operations
Unmitigated	Truth Tracks	NASA Briefing Mar. 2019	NASA Briefing May 2019
	Noisy Tracks	NASA TBD	
Mitigated	Truth Tracks with a Simple Phase 1 Pilot Model	Lincoln Lab (LL) Briefing Mar. 2019	Cal Analytics (CAL) Briefing Mar. 2019
	Noisy Tracks with a Revised Pilot Model	NASA Oct. 2019	

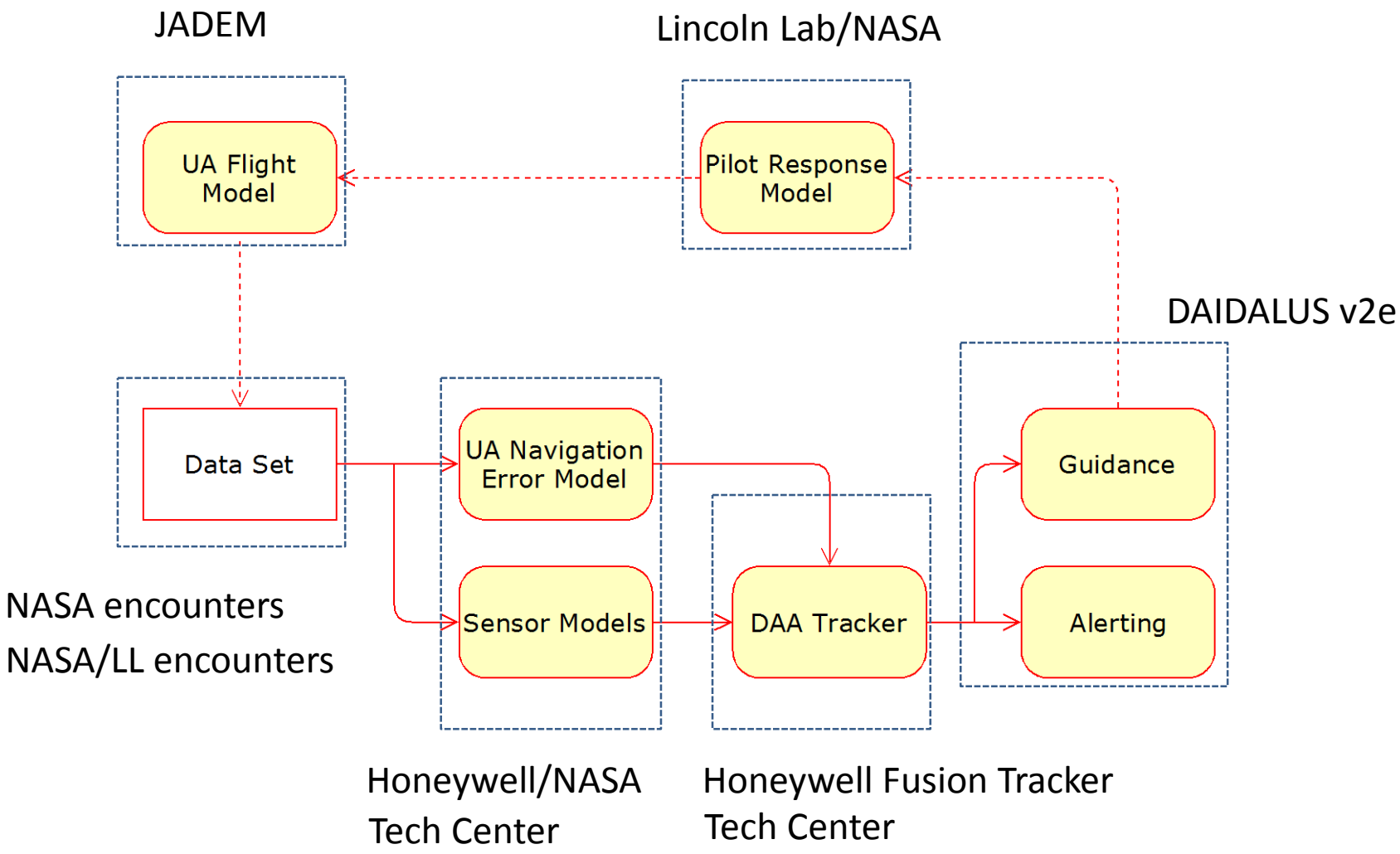
Test Matrix

- Sensor volume and uncertainties
  - Surveillance volume of three radar classes
  - Truth tracks vs. noisy tracks
- DAIDALUS
  - with SUM
  - without SUM
- Pilot response model
  - NASA revised model for low SWaP
  - The Phase 1 Lincoln Lab model

Primary Performance Metrics

- Safety Metrics
  - Near-mid-air-collision (NMAC) risk ratio
  - Loss of DWC (LoDWC) ratio
  - Severity of LoDWC
- Operational suitability metrics
  - Alert ratio
  - Maneuver duration time
  - Alert stability
  - …

Simulation Architecture



Challenges

- Low SWaP radar model parameters
  - NASA flight test 5 radar data were not enough for calibrating the model
  - NASA flight test 6 will not start data collection until late August
  - Mitigation: will use theoretical values obtained from Honeywell and rerun simulations later if necessary
- DAIDALUS SUM parameter tuning task delayed
  - NASA has just started looking into this due to other tasks taking precedence
  - A few issues in V2 were found and addressed just recently (March and April 2019)

Timeline

- June 2019:
  - Sensor model discussion with the M&S sub-working group
- July 2019
  - Pilot model discussion with the M&S sub-working group
  - Data collection
- October 2019
  - Results briefing
- December 2019
  - Additional results briefing

Related Activities

- NASA/Honeywell Flight Test 6 (Aug. – Dec. 2019)
- Low SWaP HITL (Sep. 2019)
- Low SWaP sensor surveillance volume analysis
  - Repeat Appendix B of DO-366 (AAG, Jul. – Oct. 2019): Maneuver initiation range analysis based on the non-cooperative DWC Repeat Appendices C and D of DO-366 (CAL, May -- Oct. 2019):
    - Probability of an Intruder Entering the Field of Regard within the Declaration Range
    - Validation of Radar Declaration Range (RDR) against DAA Alerting Requirements
- DAA closed-loop simulation with an EO/IR sensor (LL, May to Dec. 2019)
- Active surveillance omnidirectional antenna analysis (LL, May to Dec. 2019)

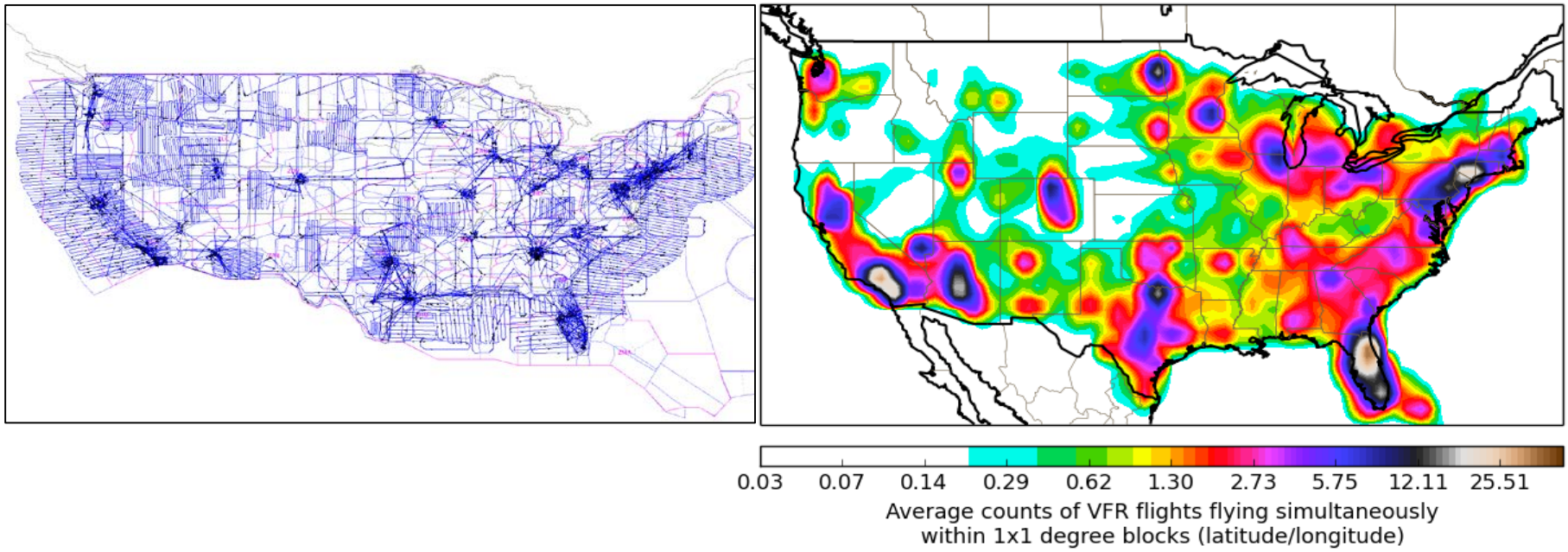
Backup Slides

Additional Performance Metrics

- Alerting Performance Metrics
  - Average alert time
  - Late alert probability
  - Short alert
  - Missed alert probability
  - Correct required alert
  - Correct required non-alert
  - …

Encounter Set

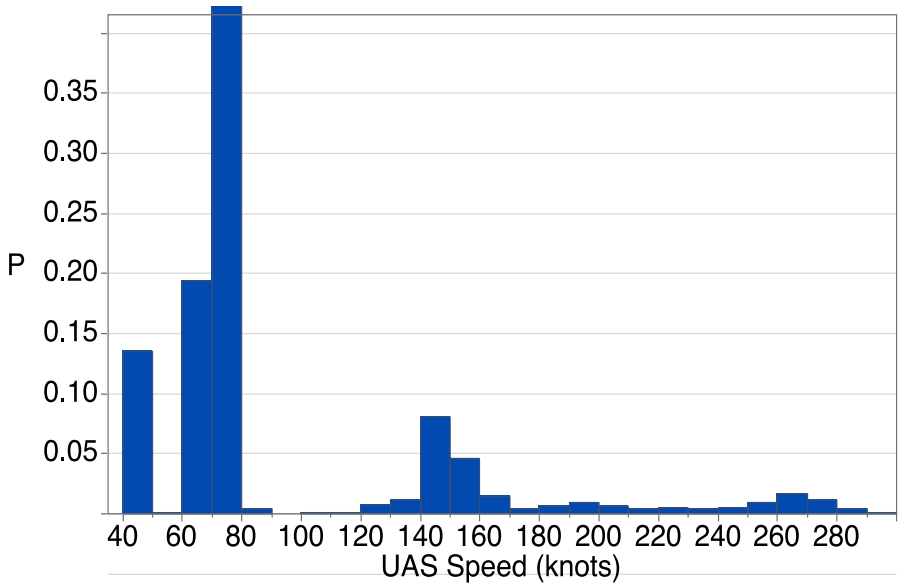
- 17,100 hours of projected UAS mission trajectories in one day overlaid with each of 21 days' radar recorded visual flight rules (VFR) traffic
- Only encounters between 500 ft AGL and 10,999 ft MSL are analyzed

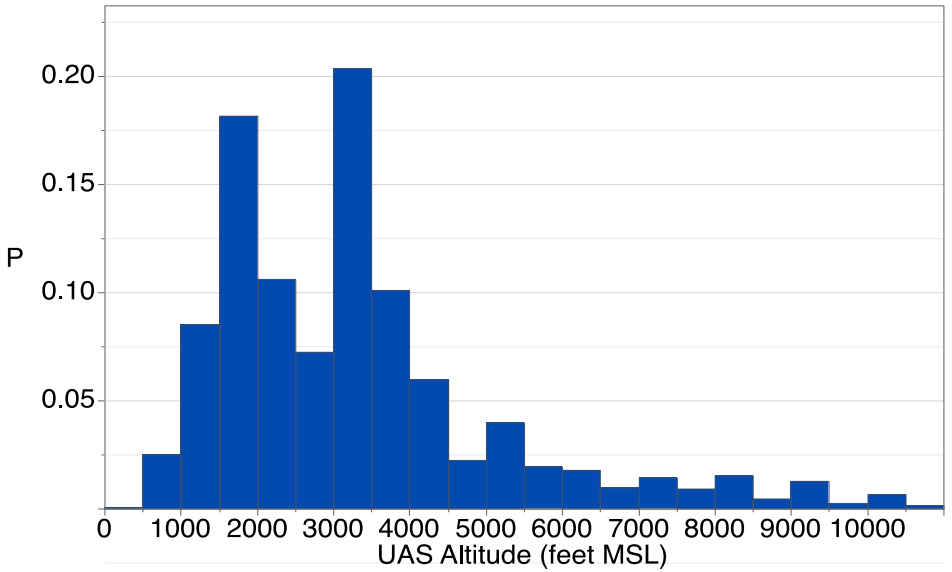


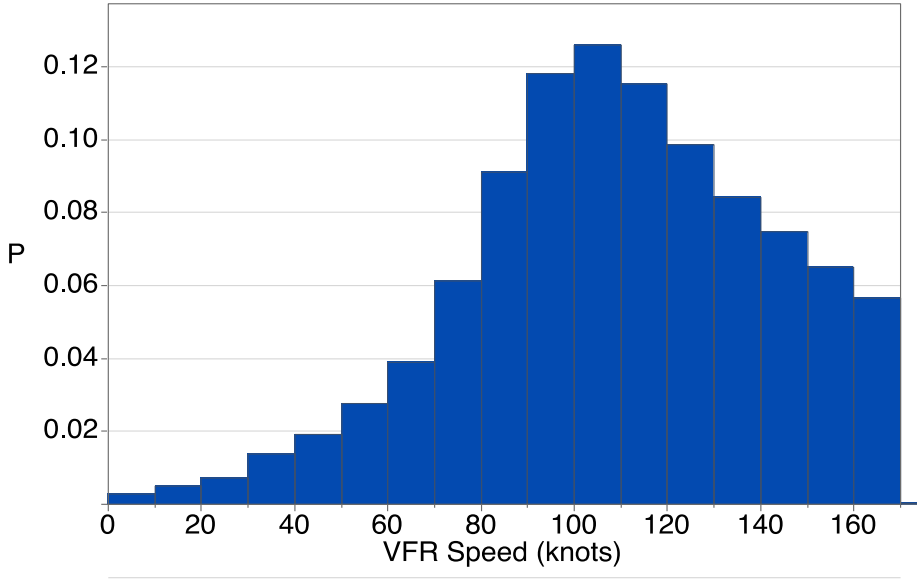
UAS Missions

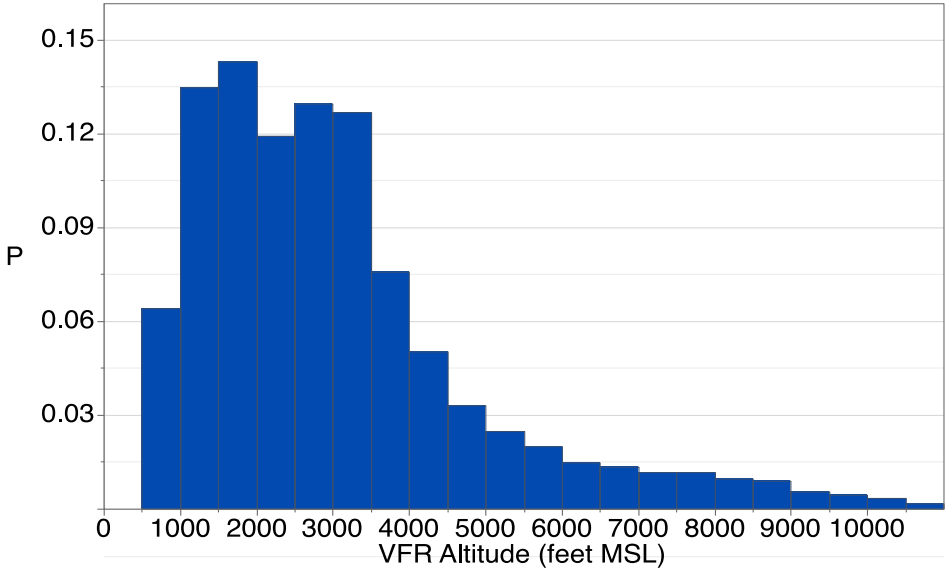
Number	Mission Types	Airspace	UAS Group	Cruise Altitude	Cruise Speed (KTAS)	Flight Pattern
1	Aerial Imaging and Mapping	Flights depart from and return to a regional airport located within 40 nmi. of OEP 35 airports; Class D, E, and G (including Mode C Veil) with Class B or C transition	Aerosonde Mk 4.7	3000 ft. AGL	44 to 51	Radiator-grid pattern or circular pattern
2	Air Qualtiy Monitoring	Flights depart from and return to a regional airport located within 40 nmi. of OEP 35 airports; Class D, E, and G (including Mode C Veil) with Class B or C transition	Shadow-B (RQ7B)/NASA Sierra	4k, 5k, and 6k ft AGL	74 to 89	Radiator-grid pattern
3	Airborne Pathogen Tracking	Flights depart from and return to a regional airport located within 40 nmi. of OEP 35 airports; Class D, E, and G (including Mode C Veil) with Class B or C transition	Shadow-B (RQ7B)/NASA Sierra	3,000 ft., 5,000 ft. and 10,000 ft. AGL	72 to 97	Radiator-grid pattern
4	Flood Inund. Mapping	Flights depart from and return to a regional airport located within 40 nmi. of OEP 35 airports; Class D, Mode C Veil, E, and G	Aerosonde Mk 4.7	4,000 ft. AGL	46 to 51	Grid pattern
5	Flood Stream Flow	Flights depart from and return to a regional airport located within 40 nmi. of OEP 35 airports; Class D, Mode C Veil, E, and G	Aerosonde Mk 4.7	4,000 ft. AGL	46 to 51	Grid pattern and/or along stream direction
6	Law Enforcement	Flights depart from and return to a regional airport located within 40 nmi. of OEP 35 airports; Class D, E, and G (including Mode C Veil) with Class B or C transition	Aerosonde Mk 4.7	3,000 ft. AGL	44 to 51	Three types of pattern: 1) grid pattern, 2) random, 3) outward spirial
7	Point Source Emission	Flights depart from and return to a regional airport located within 40 nmi. of OEP 35 airports; Class D, Mode C Veil, E, and G	Shadow-B	3,000 ft. AGL	72 to 80	Grid pattern and/or along stream direction
8	Spill Monitoring	Flights depart from and return to a regional airport located within 40 nmi. of OEP 35 airports; Class D, Mode C Veil, E, and G	Shadow-B/Sierra	3,000 ft. to 13,000 ft. AGL	72 to 93	Up and down-wind flights in a radiator-grid pattern, Round-the-clock
9	Tactical Fire Monitoring	Flights depart from and return to a regional airport located within 40 nmi. of OEP 35 airports; Class D, E, and G (including Mode C Veil) with Class B or C transition	ScanEagle/Shadow-B	3,000 ft. AGL	72 to 75	Circular flight path following the perimeter of a wildfire
10	Traffic Monitoring	Flights depart from and return to a regional airport located within 40 nmi. of OEP 35 airports; Class D, E, and G (including Mode C Veil) with Class B or C transition	Shadow-B	1,500 ft. AGL	58 to 84	Geo-spatial monitoring flight path
11	Wildlife Monitoring	Flights depart from and return to a regional airport located within 40 nmi. of OEP 35 airports; Class D, Mode C Veil, E, and G	Aerosonde Mk 4.7	3,000 ft. AGL	44 to 51	Radiator-grid pattern
12	News Gathering	Flights depart from and return to a regional airport located within 40 nmi. of OEP 35 airports; Class D, E, and G (including Mode C Veil) with Class B or C transition	Aerosonde Mk 4.7	1,500 ft. to 3,000 ft. AGL	44 to 51	Random-path: e.g., police-chase; Circular orbit:

Speed and Altitude of UAS and VFR Traffic









Encounter Statistics

- Total number of pairwise encounters with 21 days of traffic
  - 94,081
- Total number of NMAC: 505 Near Mid-Air Collisions
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UA Speed Range (KTAS)	40 to 100 kts	100 to 150 kts	150 to 200 kts	200 to 291 kts
# Encounters	72667	9062	7040	5312

- Total number of LoDWCs
  - Non-coop DWC: 9958
  - Phase1 DWC: 24809

Number of LoDWC